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ABSTRACT

Presented are seven Information Bulletins from the Calculator Information Center. Each addresses concerns that have arisen as teachers consider the use of calculators or begin to use calculators. Bulletin No. 1, prepared by Higgins, discusses "Types of Calculators." The second bulletin, compiled by Channell, presents some suggested activities for secondary school teachers. The third bulletin is a compilation of "Suggestions for Calculator Selection" at the elementary school level. Fourth is an information bulletin for administrators, prepared by Jones and Fosley. Bulletin No. 5, developed by Gawronski, is on "Leading a Calculator Workshop." The sixth bulletin, prepared by Denman, contains suggestions for using calculators in grades 1-3, while the seventh bulletin, developed by Immerzeel and Ockenga, presents activities for using calculators in grades 4-6. (MS)

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INFORMATION BULLETINS FROM

THE CALCULATOR INFORMATION CENTER

BULLETINS 1-7

edited by

Marilyn N. Suydam

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CALCULATOR INFORMATION CENTER

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Types of Calculators
Bulletin developed by Jon L. Higgins

Information Bulletin No. 1
January 1978

Perhaps "a rose is a rose is a rose", but it is not true that "a calculator is a calculator is a calculator"! The way one enters information into a calculator, and the way the calculator processes the entered information, varies according to the brand and the model calculator being used. While there is a wide variety of calculator types, there are three basic variations (and a minor combination) that you should be aware of.

The first, and perhaps simplest of these, accepts numbers and operations just as they are written in horizontal mathematical notations. That is, to do the problem 2+3=, one simply keys in 2, [+], 3, and [=]. Perhaps the most important key is the [=] key, for it actually instructs the calculator to execute the operation which was keyed in previously. This seems natural for problems written in horizontal notation, but it can be confusing for young children if they have only seen a vertical format such as $\begin{array}{r} 2 \\ +\ 3 \\ \hline \end{array}$. Not only is there no = sign in a vertical format, but the horizontal line is important in signaling the end of the problem statement. Of course, there is no horizontal bar on any calculator keyboard. Fortunately, the elementary mathematics curriculum has attempted to make children comfortable with both horizontal and vertical formats for many years now. Widespread adoption of hand-held calculators, however, may finally provide a reason for emphasizing the horizontal format.

When a series of arithmetic operations is entered into calculators of the first type, the calculator processes the operation in the order in which they are entered. Thus the expression

$$2 + 4 \times 5 - 9 \div 3 =$$

would be evaluated as $6 \times 5 - 9 \div 3 =$

then as $30 - 9 \div 3 =$

and finally as $21 \div 3 = 7$

This procedure seems perfectly reasonable until one begins to include fractions in the arithmetic operations. A type 1 calculator would evaluate the expression

$$1/2 + 1/4 = \text{as}$$

$$1 \div 2 + 1 \div 4 =$$

or $0.5 + 1 \div 4 =$

or $1.5 \div 4 = 0.375$

This is a disastrous state of affairs, since the correct answer is 0.75! One way to avoid this difficulty is to agree on a new order of operations: evaluate all multiplications and divisions in an expression first, and evaluate the additions and subtractions last. With this agreement, 1 ÷ 2 + 1 ÷ 4 =

becomes 0.5 + 0.25 = 0.75

Because of difficulties such as this, a second-type calculator has been constructed which follows this new rule of order. It would evaluate the expression

2 + 4 x 5 - 9 ÷ 3 =

as 2 + 20 - 3 = 19.

Type 1 calculators which process all operations in the order in which they are entered are known as algebraic logic calculators. Type 2 calculators which perform all multiplications and divisions in an expression before evaluating additions and subtractions are known as algebraic operating system calculators.

It is not easy to modify a type 1 calculator to perform like a type 2 calculator unless the calculator has a memory. But it is relatively easy to make a type 2 calculator perform like a type 1 calculator. The secret is simply to have each operation performed before the next operation is keyed in. The simplest way to remember to do this is to press the [=] key after each operation expression is completed. That is, if you are using a type 2 calculator and want it to evaluate the expression 2 + 4 x 5 - 9 ÷ 3 = in the same way as a type 1 calculator, you should use the following key sequence:

2, [+], 4, [=], [x], 5, [=], [-], 9, [=], [÷], 3, [=].

(This is the simplest procedure to remember. But it is not the most efficient procedure. Since the type 2 calculator performs multiplications and divisions first, it is really only necessary to press the equal key after additions and subtractions. Thus the sequence 2, [+], 4, [=], [x], 5, [-], 9, [=], [÷], 3, [=] will give the same results. For beginners, however, the longer procedure is more consistent and less confusing.

There is another major type of calculator that is available to students. The type 3 calculator (Reverse Polish Notation) focuses upon the arithmetic operations as functions on ordered pairs of numbers. That is, addition matches the number pair (15, 10) with the number 25. Subtraction matches (15, 10) with 5. Multiplication matches (15, 10) with 150. Division matches (15, 10) with 1.5. The order of the numbers in the pair is important, since not all operations are commutative. For subtraction (15, 10) is matched with 5, but (10, 15) is matched with -5. Because of this focus on number pairs, a type 3 calculator requires that both numbers be entered before the operation is specified. Thus a type 3 calculator has a key on the keyboard just for entering numbers. That key is usually marked [ent]. To add 2+3, key in 2, [ent], 3 (which establishes the ordered pair (2, 3) and then instruct the calculator which operation function to perform by pressing an operation key. Thus the complete keystroke sequence for adding 2 + 3 is:

2, [ent], 3, [+].

Pressing the operation key actually performs the operation, so that no [=] key is necessary. The absence of an [=] key is the easiest way to identify a type 3

(Reverse Polish Notation) calculator. Less expensive type 3 calculators omit the [ent] key and use the [+] key both to enter numbers and to perform the addition operation.

Finally, some calculators act like a combination of type 3 and type 1 calculators. These calculators work with Reverse Polish Notation for addition and subtraction, and with algebraic logic for multiplication and division. They are most easily identified by double marked keys [+ =] and [- =] Many business calculators and printing calculators use this combined system, known as arithmetic logic. Because this combination logic could be confusing, these calculators probably should not be used with young beginning students.

Each of the three major types of calculators has its own advantage. A type 1 calculator operates just as a person with minimal mathematics training would expect that it should. A type 2 calculator operates consistently with conventions made in algebra. A type 3 calculator emphasizes ordered pairs and functions. As we have tried to point out, it is not difficult to switch back and forth between different types of calculators. But it is risky to approach a new calculator and assume that it will work exactly like your old familiar one.

This Information Bulletin was prepared by Jon L. Higgins, The Ohio State University.

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Calculator Activities for
Secondary Grades

Information Bulletin No. 2
December 1977

Collected and developed by
Dwayne Channell

The hand-held calculator is becoming a very common item of interest to secondary school students and teachers. Not only can the calculator perform computations quickly and accurately: it can do this for a very small cost. It is no longer unreasonable to assume that a secondary math classroom be equipped with several calculators. However, it is important that these calculators be used for more than checking answers and playing games. With a little effort every teacher can create activities which take advantage of the calculator's quickness to reinforce and extend concepts and to develop problem solving. It is the purpose of this information bulletin to suggest several such activities. No attempt has been made to cover the more advanced levels of the secondary mathematics curriculum. Instead, activities that can be used with the majority of students are suggested. It is the hope of the author that these activities will serve to direct thinking toward the development of useful activities which take full advantage of the hand-held calculator as an educational aid.

Investigate the pattern in the decimal remainders for each set of problems

a. 11÷5, 12÷5, 13÷5, ..., 20÷5
b. 15÷7, 16÷7, 17÷7, ..., 28÷7

Key in '8213.5467'. Replace the '6' with a zero without changing the remaining digits.

Many digit sequences form words when the calculator is inverted. The following code is used:

8=B, 7=L, 6=g, 5=S, 4=h, 3=E, 2=Z, 1=I, 0=O

Work the following problem and invert your calculator to determine what Pat needs to buy before playing tennis.

$$18(147\cdot 20+19\cdot 367\div 1000)$$

If a square has an area of 529 cm^2, what is the length of a side? What if the area is 158 m^2?

Begin at zero and make your calculator count by ones until you reach one thousand. How long did it take? Now begin at zero and count by .01s until you reach ten. How long did this take? Compare the two results.

$100 is invested at 5.25% annual with the interest left to compound. How long will it take to double the investment? How much would the investment be worth after 100 years?

Collect several circular objects. Estimate the decimal value of π by measuring the diameter and circumference of each object and computing an average ratio.

Use a wrist-watch with a sweep-second hand to determine how far the tip of the second hand travels in a 24-hour period. How far would it travel in 5 years?

If squares are to be cut from the corners of a square paper 25 cm on a side so that the paper can be folded into a "topless" box, what is the largest possible volume this box can have?

Calculate the thickness of one page of your mathematics textbook.

Estimate the number of blades of grass on the school football field.

Which is a better salary to earn over a 30-day period, Plan A or Plan B?

	Day 1	Day 2	Day 3	Day 4	etc.
Plan A	$1	$2	$4	$8	etc.
Plan B	$100	$200	$300	$400	etc.

Consider the natural numbers n from 1 through 25. Calculate 1÷n for each n. Can you predict for which n the calculation will fill the display (i.e., not terminate)? Test your prediction for $n \geq 26$.

Make your calculator display the following number sequences. In each case, find the 10th and 20th terms in the sequence.

a. 4, 8, 16, ...
b. 4, 8, 12, ...
c. 25, 16, 7, ...
d. 2, -6, 18, ...

Find a number m so that m x m x m = 15.

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Suggestions for Calculator Selection

Information Bulletin No. 3
June 1978

This is a synthesis of considerations and appropriate suggestions for selecting a calculator for elementary school use. Most of the considerations are also appropriate for secondary school users, but such factors as the number of functions, the type of logic, and programming capability assume increased importance in upper-level courses. For additional information, check the references in Reference Bulletin 12.

Note that it is important that a calculator be selected in relation to anticipated curricular applications. It is strongly suggested that the way a particular calculator operates should be checked carefully: test the calculator before you buy a classroom set to be sure it will serve your needs.

Things to Consider	Suggestions for Elementary Level
Type of logic	Commercially known as "Algebraic" (allows data to be entered as mathematical sentences are usually written; see Information Bulletin 1 for a discussion of types of logic)
Number of functions	At least +, -, x, ÷
Type of decimal notation	Floating decimal point; negative sign that immediately precedes a negative number; check the way the calculator rounds numbers
Overflow or error indicator	Clear indication of when display, input, or processing limit is reached, or when "illegal" operation is used
Type of display	8-10 digits; easily readable; acceptable viewing angle (depends in part on how many persons are to view--one child or more than one; how calculator must be positioned); note that the vision-impaired child may have difficulty with certain types of displays (see also comments on page 3)
Role of keys	In general, each key should have only one purpose
Keyboard format	Configuration of keys should facilitate accurate entry; easily accessible on-off switch--check the ease with which it works; adequately sized keys; keys should give some response when pressed (click, beep, or other sense); note the position of the numeral in relation to the keys

Things to Consider	Suggestions for Elementary Level
Size and weight	Appropriate for the user
Power source	Should provide long service, conserve energy. One opinion: "Consider the number of operating hours per battery replacement or charging. Automatic power-down displays and delayed power-off features insure the maximization of battery life. Long-life replaceable batteries seem to be the most cost- and time-efficient. Charging batteries and contending with electrical cords can be tedious." (Caravella, 1976, p. 548)
Special keys constant (K), change sign (+/-), parentheses, square root, percent, fraction, squaring	Analysis of the curriculum in which the calculator is to be used will aid in deciding how important these keys are to the user (for example, the +/- key is important if you want convenient manipulation of integers); generally you will have to "trade" some features for others you consider more desirable. Note how the keys handle the procedures.
Memory: two-key	Stores (STO) the displayed number for later recall (RCL): a useful feature for users even at early levels
four-key	Allows functions, usually addition (M+) and subtraction (M-), to be performed on the content of a memory register, with retention for later recall (MR); includes "memory clear" (MC): could be useful at upper levels
Memory indicator on display	Helpful; make sure that it is easy to interpret the symbol (for example, an "M" is easier than a ".")
Scientific notation	Note when and how it works (it may "cover up" repeating decimals)
Automatic constant	Allows calculator to count: note for which operations a constant applies, and the position of the number treated as the constant--note also that it may operate differently with different functions.

Things to Consider	Suggestions for Elementary Level
Printout	Not worth the current cost--but could be helpful to some users if cost dropped; note that a printout may take an unexpected form--check how symbols appear
Durability	Check on droppage, malfunctioning incidents, etc., and weigh this in relation to cost
Cost	Within the budget . . .
Reliability of manufacturer	Adequate (12-month) warranty; repair service
Reliability of vendor	Prompt, responsive service

Types of Display

Currently two different types of display are available: LED (Light Emitting Diode) and LCD (Liquid Crystal Display). Each has advantages and disadvantages.

LED	LCD
in use longer	more recently on market
less expensive	slightly more expensive
uses 9-volt battery: relatively short life	uses silver oxide battery: hundreds to thousands of hours of life
durable (depending on the particular calculator)	less stable, reportedly (e.g., dropping may cause display to shift or lose part of a symbol)
"flashing" of symbols	"immediate" displays of symbols
can be read in dark	depends on good reflected room light
red numerals or blue/green numerals: higher battery drain for blue/green than for red numerals	black numerals on gray, yellow: low battery drain
red numerals not readable from wide angle; blue/green generally readable from wider angle	readable from wide angle (in good light)

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Information
Bulletin No. 4
December 1978

CALCULATORS AND INSTRUCTION:
An Information Bulletin for Administrators

Prepared by Mary Harley Jones and R. C. Bosley

Now that calculator costs have stabilized at very affordable levels for any school, the potential of the calculator as an aid to a school's total instructional program is indeed great. In every discipline where problem solving with quantitative data is a basic skill, the calculator is a tool which relieves students of computational loads and frees them to focus on the primary learning objectives of interpreting the written word, analyzing information, formulating solution strategies, drawing conclusions, and making decisions. Although very useful in science, social studies, business, economics, home economics, and vocational classes, the calculator is most useful in mathematics instruction at all grade levels.

Calculators will not eliminate the need for students to acquire paper-and-pencil computational skills; rather, they will aid the student in understanding the concepts and algorithms necessary to the development of computational skills. Calculators, like computers, cannot replace the need for knowing how to solve problems; they can produce correct answers only when the RIGHT buttons are pushed. If a student does not know when or with which numbers to add, subtract, multiply, or divide, the calculator is useless. Calculators, appropriately used as an aid, can improve mathematics instruction.

The success of any new instructional aid or program in a school depends on informed administrative leadership. For effective calculator-aided instruction, administrators should be aware of appropriate instructional uses of the calculator. Selecting the most suitable calculators for a school, managing their storage and distribution with ease and efficiency, formulating guidelines for their use, and providing in-service training to teachers are also critical aspects which an administrator will need to address.

Instructional Uses

The following examples of appropriate uses are not exhaustive, but illustrate the ways calculators can aid in mathematics instruction.

> Pattern Perception. Perceiving mathematical patterns leads to discovery and understanding of significant mathematical concepts. Skip counting is the pattern leading to multiplication concepts and acquisition of multiplication facts. A number line, a hundreds chart, a calculator, or all three reveal skip counting patterns. With a calculator, the pattern emerges with great speed and accuracy. Multiplication and division by powers of ten form patterns essential to estimation skills and ability to use scientific notation. A discovery-type lesson on these patterns is more efficiently accomplished with a calculator than with paper and pencil because of the time saved in generating the patterns.

Concept Development. One advantage calculators bring to conceptual development is the reduction of the interference of lengthy, time-consuming computation with the developmental steps in presenting the concept. The relationship of a circle's circumference to its diameter is a concept students develop in the middle grades and is usually their first exposure to an irrational number. This concept is frequently developed by having students measure the circumference and diameter of several circular objects of varying size and finding the quotient of the measures of the circumference and the diameter. If the long division with numbers similar to 6 7/16" and 2 1/16" is correctly completed, all quotients are very close to 3.14, no matter whether the circular object was large or small. The point of the lesson is often lost in the tediousness of the difficult divisions. If the divisions are done on a calculator, accurate answers quickly obtained keep the point of the lesson, $C \div d = \pi$, constantly in focus.

Problem Solving. Removal of the time-consuming computations involved in many problems enable the student to focus, without undue interruption, on the process(es) required for correct problem solution. The time saved will allow the teacher more time for instruction on problem-solving skills and will allow the student time to attempt more problems.

Real Problems. The application of mathematical skills to solving real problems serves to make mathematics a more meaningful endeavor for students. Teachers rely heavily on textbook-type, contrived problems simply to control size and difficulty of numbers with which the student must deal. With the aid of the calculator, this is no longer an obstacle to solving real problems.

Enrichment. Some enrichment activities present fairly heavy computational requirements. The student typically involved with this type of activity is a good computer. The calculator can remove the boredom of extensive computation for this student.

Skill Reinforcement. Calculator use in drill and practice has been a point frequently made in the literature and has been the primary focus of much of the commercial calculator-based instructional materials. Misuse of the calculator most often occurs in this area; however, there are many productive ways to use the calculator for drill and practice purposes. Using the calculator to practice estimation skills by having students confirm their estimations with quickly produced calculator answers provides the immediate verification students need to sharpen estimation skills.

Selection

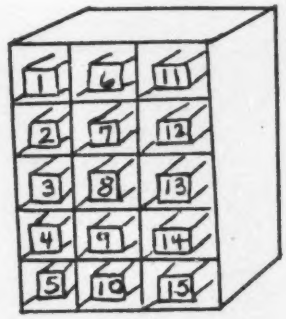
There are vast differences in the many calculator models available on today's market. Some are unsuitable for school use and no single model will be suitable for all students in a school district. An appropriate model for elementary students might not feature the capability of entering negative numbers, but this feature is essential for students in advanced high school mathematics and science classes. Assessing the needs of the student-user is the first step in selecting a calculator. Other important considerations are cost, warranty and service, type of logic, type of display, power source, memory, key size, readability of display, and appropriate functions. Detailed information on these considerations is the subject of Information Bulletin No. 1 and 3, available from the Calculator Information Center.

Since manufacturers phase in and phase out calculator models as frequently as automobile manufacturers, it is important to purchase, at one time, the desired number of units of the particular model chosen. For ease of use by student and teacher, it is best that each student in a class have the same model calculator. We strongly recommend that calculators be purchased in classroom sets.

To minimize battery replacement cost, careful consideration of the type of calculator display is recommended when selecting a calculator. The available types of display have varying degrees of drain on batteries. Calculators using silver oxide or mercury batteries can provide thousands of hours of computing time, and should be considered as alternative to the purchase of calculators with adaptors. Adaptors, if desired, should be purchased at the same time as calculators. Consider the number of electrical outlets in rooms and the possible ways the calculators might be used in stationary situations (i.e., learning centers or laboratories) in deciding on the number of adaptors to purchase. Four or five adaptors per classroom set of calculators is probably sufficient for most situations.

Control, Storage, and Security

Theft and loss rates have been negligible in schools where simple but effective storage systems are used. A classroom set of calculators should be stored in a box or carton with pigeonholes for each calculator. Each calculator should be numbered so that the number is visible when the calculator is in the box. Students can be assigned calculators by numbers, if desired, but a quick, visual check at the end of the period of use will provide necessary classroom security. Such a case would be light enough for carrying to the school office for overnight storage, if desired, and small enough to fit in a teacher's classroom storage closet or cabinet. If a calculator is borrowed from a set by a teacher, administrator, or student, a check-out system is recommended to record the whereabouts of the "loose" calculator.



Initial and Maintenance Costs

The calculator is no longer the economic marvel which dramatically decreased in unit price while product quality steadily increased. Calculator costs have stabilized at affordable levels for almost any school budget. The initial cost is comparable to that of a textbook. A calculator appropriate for elementary and middle schools can be purchased for $7 to $20. Suitable calculators for high school use currently vary from $13 to $50 each. If students and staff are instructed on proper care of the calculator, as with any other tool or instructional aid, maintenance costs will be minimal.

Tips for proper care include:

Turn calculators off when not in use to conserve battery energy.

Keep calculator on a flat surface or a stand, away from the edge of the table or desk.

Remove batteries and store in a cool place when calculators are not in use for a long period of time such as summer vacation.

Teacher Training

As with any new instructional aid, teacher training on calculator use is important. This need not be an expensive nor a lengthy project. A school district's mathematics supervisor or curriculum specialist could conduct the training, as could a teacher experienced in the use of calculators. Six to 12 hours of workshop-type in-service should suffice. The in-service should include a thorough treatment of appropriate and inappropriate instructional uses of calculators, with stress on utilization in well-planned lessons with clear-cut objectives as opposed to utilization on a haphazard basis. Informing teachers of the school's and/or school district's guidelines on calculator use should also be an in-service topic. (Information Bulletin No. 5 provides suggestions for workshop leaders.)

Guidelines for Calculator Use

We strongly recommend that a school and/or school system set guidelines for calculator use. The following are suggested as a minimum:

1. Use of calculators must not replace needed student understanding and skill in mathematical operations and algorithms. However, when teaching basic computational algorithms, the calculator can be a useful tool for focusing on various aspects of an algorithm such as partial products in multiplication.

2. Each student should have equitable access to calculators whenever they are used in classroom activities.

3. In evaluative testing situations, all students must have equal access to calculators; where equal access cannot be provided, no student should be permitted to use a calculator.

4. Avoid use of the calculator in ways which cause students to view essential learning objectives as antiquated and/or useless because of the speed and ease of computation on the calculator. Using the calculator solely or primarily for checking paper-and-pencil work has this inherent danger. If calculators are used for checking, consider having students check using the inverse operation; this provides for reinforcement of the inverse relationships between operations and perhaps for greater understanding of the algorithm. For example, when the student has completed, with paper and pencil, a long division example with a remainder, have the student check on the calculator by multiplying the quotient by the divisor and adding the remainder to that product.

This bulletin was prepared by Mary Harley Jones and R. C. Bosley, Fairfax County (Virginia) Public Schools.

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Information Bulletin No. 5
December 1978

LEADING A CALCULATOR WORKSHOP

Prepared by Jane Donnelly Gawronski

The use of calculators in the mathematics classroom is of great interest to school staffs and school community groups. Workshops and in-service programs on calculator use are often planned and conducted in response to this interest. If you are responsible for conducting or leading these activities, there are several things you can do to help to insure their success.

BEFORE THE WORKSHOP

First of all, select appropriate objectives for the workshop. These are not really intended as rigorous behavioral objectives for the workshop participants to master or to be pretested and posttested, but rather these objectives are to help you in selecting activities and materials for workshop participants to use. These objectives may include:

A) To have the participants become familiar with how to use a calculator.

B) To demonstrate calculator activities for specific topics, such as computational skills, geometry, order of operations, and problem solving.

C) To identify how to use the calculator in the classroom: management, storage, maintenance, record keeping, etc.

D) To become familiar with how to plan and conduct in-service programs on calculator use.

Once you've selected your objectives, you can consider ideas, activities, and materials that will help you to accomplish them. Fortunately, there are many books, pamphlets, and task cards commercially available, as well as articles in the literature. See the Calculator Information Center Reference Bulletins for comprehensive lists of these resources.

GETTING STARTED

Share your workshop objectives with the participants. This is helpful for the participants and lets them know what to expect to have an opportunity to learn. It is critical, however, to begin with activities that are non-threatening, low-risk for participants and that have a high potential for success. The calculator is still recent technology and must be introduced to many teachers. It's the children who are growing up with this technology in the world around them who accept it as a matter of course. Adults may sometimes be reluctant or inhibited. Some of the letter-number activities are appropriate as intro-

ductory vehicles for adults. For example:

1. Did you know your calculator was bilingual?

   Key in 15, and turn your calculator upside down.

Or, 2. Did you know your calculator can display the name of a best seller?

   Key in 37818, and turn your calculator upside down.

Activities like this one can give the novice calculator user some non-threatening practice with keying in numbers, reading calculator numerals, and checking the display. A quick introduction to addition, subtraction, multiplication, and division can follow immediately.

INTRODUCING THE KEYS AND ACTIVITIES

When an operation such as addition is introduced, "how to key in" addition examples should be discussed. The need for using the CLEAR and/or CLEAR/CLEAR ENTRY keys before entering a problem should be demonstrated. It is also helpful to start with an example for which participants already know the answer. This way they can verify for themselves that they are using the calculator correctly. An example such as the following can be used:

Example: 7 + 8 = ?

Calculator Solution: [C] 7 [+] 8 [=] DISPLAY 15

After introducing how to add using a calculator, lead participants in problem solving or exploratory activity requiring addition. For example:

1. Make your calculator display 895 using only the 1, 0, [+], and [=] keys.

Or, 2. How many different ways can you find to express 763 as the sum of primes?

The grade level interests and mathematical backgrounds of the workshop participants should help you to select appropriate activities for this.

This same general procedure can be used to introduce the operations of subtraction, multiplication, and division, as well as how to use special keys such as % or $\sqrt{\ }$. First, introduce the use of the calculator with a problem participants are apt to know the answer to (you may want to do more than one of these). Second, follow this with an activity where the use of the calculator is obviously an important asset for finding the solution.

Additional ideas and activities should be selected so they illustrate your objectives. A review of the materials cited in Calculator Information Center Reference Bulletins on "Instruction with Calculators" and "Books" will provide you with a variety of place value, computational, and problem-solving activities to use.

SUPPLIES

Participants should be provided with a copy of appropriate visuals as well as a "handout" for them to use. This way they can closely follow your presentation and practice or try out the ideas and activities.

It is also desirable if participants have their own individual calculators. If not, a calculator can be shared by two or more people. In fact, you may want to use activities that are designed so only one calculator is required for a group of two to four participants. However, if you have access to a classroom supply of calculators, by all means use them. But do not be surprised if participants bring their own calculators to use. This is all right and, in fact, may even be better. If they know how to use their own calculator and all its keys, then they are probably more apt to make effective use of the calculator in the classroom. In addition, this can provide a bit of "show and tell" atmosphere and more participant involvement in the workshop. Also, it provides an opportunity to identify characteristics of different calculators, since some calculators have Liquid Crystal Displays (LCD) and others will have Light Emitting Diode (LED) displays. Some calculators have special keys that do not appear on most simple four-function calculators. If your workshop objectives include one on calculator technology, you may want to go into some detail and indicate advantages and disadvantages of particular features of calculators.

ENDING YOUR WORKSHOP

At the conclusion of your workshop you might want to give participants a "Certificate of Competence with the Calculator" or a "License to Operate a Calculator." This is particularly appropriate for participants who have come to their first calculator workshop. Remember, too, that throughout the workshop you have been a model for how to introduce or use a calculator appropriately. The certificate is another idea that participants may want to use in the classroom. At this point you should also provide sources for more information or ideas about calculator use. These might include:

1. How to get on the Calculator Information Center mailing list.

2. Announcement of additional workshops or National Council of Teachers of Mathematics and Affiliated Group services.

Participants should also have an opportunity to evaluate the workshop. The following is a sample evaluation form you may want to use:

SAMPLE EVALUATION FORM

Topic/Title _____ Speaker/Consultant _____ Date _____

(Circle appropriate response)

1.	Were the objectives for this session clear?	Clear	4	3	2	1	Vague
2.	To what extent were the objectives met?	Fully	4	3	2	1	Little
3.	How well was the presentation organized?	Very Well	4	3	2	1	Very Poor

4. How helpful do you think the presentation will be to your work? Very Much 4 3 2 1 Very Little

5. Did the physical arrangements help or hinder the meeting of the objectives? Help 4 3 2 1 Hinder

6. Were the related media appropriate? Very 4 3 2 1 Inappropriate

7. Was there enough time allowed to meet the objectives? Sufficient 4 3 2 1 Insufficient

RECOMMENDATIONS/CONCERNS/REMARKS

What I found most useful was:

What I would like more of is:

Additional remarks:

AFTER THE WORKSHOP

Read the evaluation form and compile the results. Use these to plan your next workshop! Modify or make changes and incorporate the evaluation results where appropriate. And GOOD LUCK!

The following checklist may help you in your planning

Calculator Workshop Checklist

1. Invitation to potential workshop participants
2. Pleasant room environment -- refreshments help
3. Calculators
4. Handouts
5. Visuals
6. Media
7. Display or sample copies of materials available
8. Evaluation forms

This bulletin was prepared by Jane Donnelly Gawronski, Department of Education, San Diego County, San Diego, California.

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CALCULATOR INFORMATION CENTER

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Information
Bulletin No. 6
January 1979

CALCULATORS IN GRADES K-3: WHY? WHAT? HOW?

Prepared by Theresa Denman

WHY?

Now why would anyone even consider putting calculators in the hands of five-year-olds? For that matter, why use them with any child below grade 4? Ah . . . but why not? After all, most primary grade pupils have seen or used these little machines at home. Low cost has made the tiny electronic boxes a necessity in even the least affluent households.

If education purports to equip students to cope with their surroundings, then one argument for using calculators with such young learners is that the machines are a viable part of their environment. Most primary pupils seem to associate the calculator with specific adult activities such as grocery shopping, check writing, home repair purchases, gasoline mileage, etc. Youngsters want to act out similar situations. The calculator is obviously an important adult "toy".

Children cannot ignore the intriguing buttons and lighted number displays. The ability to produce or banish the glowing numerals at the flick of a button is a type of control young children seldom experience. The interest-generating traits of these number machines are well-known to teachers who have found pupils crowded around a classmate with a calculator brought from home. Motivation, certainly, can be considered as a second reason for using calculators with any learner. It is wonderful to find an educational tool that really fascinates today's TV-sated youngsters. By the way, classroom experiences, recorded in educational periodicals since 1974, seem to indicate that children sustain this interest over long periods of time. Nevertheless, motivation alone is insufficient cause for using an item in the classroom setting.

Mistakes can be removed from the calculator with the push of a button. This can be a real boon for those who lack the small-muscle development that handwriting requires. This feature may be especially helpful to immature learners in grades 2 and 3.

To use or not to use calculators with very young children is not the heart of the question. The major concern is whether calculators can aid pupils in understanding concepts and in gaining skills in mathematics. Examine the usual curriculum for grades K-3. Counting; number recognition; one-to-one correspondence; betweenness; numbers before, numbers after; the number relations of greater than, less than, and equal to are important in the primary grades. While examining these ideas, children can experience some approaches to problem solving. The understanding of concepts and the development of problem-solving techniques are the most pervasive reasons for using calculators with young learners.

The educational importance of calculators has been emphasized by one writer, Joy Rogers (2f). She argues that calculators have the potential for becoming aids of enduring value much like books and chalkboards. Her four

criteria for such aids are that they be: (1) inexpensive and durable, (2) controllable by the learner, (3) able to do something the learner wants done, and (4) flexibly usable.

WHAT? Fine . . . so teachers can use calculators with primary grade learners. With the wide variety available, which kinds are appropriate for the kindergarten through third grade? Two basic types of machines are available and suitable for use with very young children. Some are preprogrammed with a wide range of capabilities. Principally, these machines present calculation examples, such as 5 + 7 = ?, one at a time. Pupils punch in their answers and the display indicates whether the particular answer is correct or incorrect. The least expensive models of this type may offer only addition and/or subtraction facts, ten in a set, in an unchanging order. The most expensive can be programmed by the teacher as to size of numbers used, kind of operation, and number of examples in each set. Of course, all sorts of options and prices exist between the two extremes. Some examples of these devices are in the list of references (4-8).

The pre-set programs limit the educational possibilities of this type of machine. The principal value is for drill and practice of skills already studied. Immediate feedback rewards the pupils and releases teachers and parents from checking answers. Because rapid recall of basic facts is so necessary for the mathematics taught in the upper elementary grades, the preprogrammed models can be helpful from the middle of grade 1 upward.

The second type of machine available for young learners is a very simple version of the hand-held calculator. Very simple must be stressed. Of course, keys for the number 0 through 9 are needed, as well as those for the operations of +, -, and x. The decimal point, equal sign, and "clear" (C) keys complete this minimal list. A "clear entry" (CE) key can be helpful. Third-grade teachers may wish for the division operation to be available as well.

The ability of the electronics industry to produce increasingly more complex and smaller calculators for little cost may eventually create difficulties in finding appropriate machines for primary youngsters. Children need calculators sufficiently large for them to handle easily. Large numerals minimize reading difficulty.

An excellent listing of desirable features for a calculator to be used in the elementary school can be found in Joseph Caravella's article, "Selecting a Minicalculator", in the November 1976 issue of Arithmetic Teacher. Information Bulletin No. 3 from the Calculator Information Center also contains an even more detailed listing of suggested features for calculators to be used in elementary schools.

One additional feature, the automatic constant, has become a necessity due to the games and activities being developed for elementary classes. Specifically, this feature allows pupils to continue to add, subtract, multiply, and divide by the number after the operation sign (the second number) by just pushing the equal sign.

For example: 6 [+] 2 [=] displays "8". Push [=] again, and "10" appears. Successive keying of [=] results in the calculator counting by 2's. Beware of machines having a K ("constant") key.

A variation on this second type of calculator is the ABLE™ machine that is a standard model with six interchangeable faces. These alternate keyboards allow access to from 5 to 15 keys in a variety of combinations.

HOW? Currently, materials for using the calculator with grades K-3 are rather scarce. Actually, appropriate activities should be very simple and few additional aids are necessary. The usual counters, number charts, hundred squares, domino cards, number lines, flash cards, and other materials can be teamed with the machines.

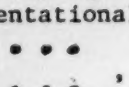
How the calculators are used with very young learners is of the greatest importance. In fact, the literature of the early 1970s suggested that children should have developed a concept of number, a system for naming numbers, and the meaning and the processes of the basic operations before calculators are used in the classroom. This caveat is softening as teachers find ways for young learners to examine counting and number sequences in a more meaningful manner. The usual lessons and materials should be used in the original development of a concept. Calculators offer variations on the theme and so serve as alternate approaches.

Allow short periods of "free play" time with any type of calculator during the initial experiences. Just let the pupils try the different buttons and observe what happens. Be sure to follow this with discussions about what the children find out. As long as the class members work actively with their machines, these warm-up discovery sessions should continue, even with older elementary children. Kindergarteners might experience only these unstructured sessions.

The electronic displays are different enough from the familiar printed numerals so that children may need some practice matching the two versions. Have pupils read some sample displays first. If they are interpreting reasonably well, get on with the active use of the calculators.

The development of rational counting can be enhanced by having the children count individual objects (manipulative level) in a set by entering 0 [+] 1 , then using the [=] to count the first item. Each time the [=] is depressed, another object is counted. Children should touch each item as they press the [=] . Each item is related to a counting number. This is experience with one-to-one correspondence.

The same activity can stress sequences. In the above case, the calculator is counting by 1's. Change the initial action to 0 [+] 2 [=] and counting by 2's is the result. At other times, the calculator can be made to count by 3's, 5's, 6's, 10's, 25's, 50's, 100's, etc. Not only are these important counting experiences, but they are also readiness for multiplication. For example, counting by 6's results in the products for the "six table".

Young learners can progress to employing calculators to associate certain dot patterns (representational level) with specific numerals. Specifically, if the pattern is  , pupils would point to each dot as they use the [=] to count by ones. This process can be reversed if small labels with dot symbols

are pasted over the calculator numbers. This forces the children to use the

for "5", etc. Change the patterns so that the fiveness is stressed, rather than the configuration. Five might be shown as or

Counting backwards is achieved by entering any large number and then [-] 1 [=] . Again, the next lower number is given with every press of the equal sign. Don't worry that eventually the display may register some negative numbers. Of course, teachers can no longer say, in the example 23 - 7 = ?, that seven cannot be subtracted from three. After all, when 3 - 7 is entered in the calculator, the result is -4. Interestingly, the Comprehensive School Mathematics Program (3) has first graders adding negative numbers. This approach seems to be easier and to give greater success than the usual subtraction algorithm.

Either counting forward or backward from a given number can allow children to see which numbers come after or before that number. Eventually, the word "before" can be replaced with the phrase "less than", and "after" becomes "greater than".

Ask the children to display "24" and then record all the numbers they find as they count by 1's to 32. The resulting list is comprised of the numbers between 24 and 32. By the way, this is definitely a problem-solving activity for grades 1 and 2, because children must be able to use the familiar counting sequence to gain new information.

Further, problem-solving skill can be obtained by asking the youngsters, "What number appears if 25 + 1 is entered and the equal sign pressed ten times?" Third graders should be allowed to guess the final number and then use the calculators to verify their answers. When children employ the calculator to find other ways of indicating a specific number, they are experiencing analysis and/or synthesis, on their own learning level. The nurturing of these higher level thinking skills depends on the young learners doing their own experimenting. Some may observe that 23 is 19 + 4 by subtracting 1 from 23 with four pushes of [=] . Others might begin with the 19 and build to 23.

All children love to check their computation with the calculator. Only after a set of exercises is completed would the calculator be employed. Pupils could use red pencils exclusively during this activity. If only one calculator is available to the entire class, have a checking corner, where one child has the privilege of performing this service. Even less able learners seem to benefit from this experience, so don't limit the most successful youngsters to being the checker.

Place value can be associated with changes displayed when "9" changes to "10", "99" to "100", etc., with the addition of 1. Even 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 shows that ten ones become one ten. Notice should be made of what happens when 19, 29, or 39, etc., have 1 added.

Again, it is emphasized that calculators operate as a means to alternative or supplementary experiences for young children. Continue to use the manipulatives like Unifix cubes, counters, attribute blocks, and counting frames for the initial teaching, as always.

Creative teachers will need to weave calculator activities into their lesson sequences. It may take considerable time for such suggestions and lesson plans to appear in textbooks and workbooks for the K-3 classes. Adapt and simplify! One exceptionally fruitful source is Math Play Therapy, Volumes I and II (3).

> One game from these teacher guides pairs children each using their own calculator. One child, who could be the less able learner, starts at "0". This player may add any chosen number at each turn. The second pupil starts at "100", and may subtract any number he or she wishes. The object of the game is to force a player to record a number the opponent is on or has passed already. For example, if the calculator which began at "0" reads "53" and the "100" machine is at "54", the first player is forced to enter [+] 1 . This child loses the game, as his or her display now shows "54" as well. This can also be a class game, with two teams each using a calculator.

Preprogrammed machines are usually furnished with an instructional manual which often contains suggestions for individual or classroom games and activities. Don't overlook these publications as sources of ideas for the classroom. Regular calculators can be used for many of these activities if the pupils key in their own examples.

Many other activities are contained in the references listed below. You and the children can experiment together! Calculators -- and very soon microcomputers -- will be fundamental tools in your pupils' educational future!

References

Teacher Resources:

1. Coxford, Arthur et al. Uses of the Calculator in School Mathematics, K-12. Monograph No. 12, Michigan Council of Teachers of Mathematics, Box 16124, Lansing, Michigan 48902. March 1977.

2. Arithmetic Teacher, Volume 23, No. 7, November 1976. National Council of Teachers of Mathematics, 1906 Association Drive, Reston, Virginia 22091.

   This entire issue is devoted to minicalculators. Of especial interest are the following articles:

   a. Bell, Max S., "Calculators in Elementary Schools? Some Tentative Guidelines and Questions Based on Classroom Experience", pp. 502-9.

   b. Bruni, James V. and Silverman, Helene J., "Let's Do It! Taking Advantage of the Hand Calculator", pp. 494-500.

   c. Caravella, Joseph R., "Selecting a Minicalculator", pp. 547-550.

   d. Immerzeel, George, "One Point of View: It's in Your Hands", p. 493.

   e. Judd, Walter, "Instructional Games with Calculators", pp. 516-18.

   f. Rogers, Joy J., "The Electronic Calculator--Another Teaching Aid?", pp. 527-530.

3. Papy, Frederique. Math Play Therapy, Volumes I and II. Comprehensive School Mathematics Program, CEMREL, Inc., 3120 59th St., St. Louis, Missouri 63139. 1978.

Preprogrammed Machines:

As with all electronic devices, refinements and modifications are causing models to change almost from month to month. Teachers should examine what is available in light of their pupils' needs. This list is not exhaustive. No specific addresses are given as most machines are handled by office machine companies, department stores, and school supply houses.

4. Digitor Learning Arithmetic Modules -- three models with increasing ranges of functions (Centurion Industries, Inc.)

5. Classmate 88 (Monroe Calculator Company)

6. Little Professor (Texas Instruments, Inc.)

7. Quiz Kid (National Semiconductor Corporation)

8. Dataman (Texas Instruments, Inc.)

Calculator with interchangeable faces:

9. ABLE™ Calculator -- this machine is available with games equipment, manipulatives, and planned lessons for early elementary pupils (Texas Instruments, Inc.)

This information bulletin was written by Theresa Denman, Detroit Public Schools.

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CALCULATOR INFORMATION CENTER

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Information
Bulletin No. 7
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HOW TO GET STARTED USING CALCULATORS IN YOUR CLASSROOM

Teachers often have questions when they get started using calculators. We have tried to answer some of these questions with examples from our classroom. We hope these tips and techniques will make getting started easier for you.

George Immerzeel
Earl Ockenga
Price Lab School
University of Northern Iowa
Cedar Falls, Iowa

CAN A CALCULATOR HELP TEACH PROBLEM SOLVING?

Teaching problem solving is one of the easiest ways to get started using calculators in your classroom. You need a good problem deck. You can either buy a deck or make your own. You can get a good start by selecting problems from out-of-date textbooks and typing them on 5 x 5 inch cards. A little art will add to the students' interest. Students will also contribute good problems if you give them a chance.

There are lots of good ways to use a deck of problem cards. You might select about 30 cards for a class of 30 pupils. Have the students work in pairs. When a pair of students solve a problem have them write their answer on the chalkboard or check with the answers that are already on the chalkboard. Of course there are lots of other ways to use your problem deck to generate a real interest in problem solving now that you have some calculators.

HOW CAN THE CALCULATOR ENCOURAGE EXPERIMENTATION?

The statements on the file card are examples of real world situations where students can perform an experiment, collect information, and then use their findings to decide if they agree or disagree with the statements.

EXPERIMENTS

Do you agree or disagree with these statements?

- It is possible to walk a kilometer taking less than 1200 steps.
- The human heart beats more than 300 million times a year.
- $500 worth of pennies laid side by side would make a line of pennies a kilometer long.

The calculator makes real world problems possible. For the first time, students can easily handle the data generated from their experiments.

HOW CAN THE CALCULATOR HELP STUDENTS REMEMBER THE BASIC FACTS?

A mental computation game that our students enjoy is "What does my calculator display?" Here is how the game is played.

The teacher gives a sequence of number facts and computes on the calculator as students compute mentally. When the teacher says "equals", students write down their final answer and compare it with the answer displayed on the teacher's calculator. A point is scored for each correct match.

Not only does this type of activity provide mental computation practice, but it also proves to students that "knowing" the basic facts is quicker than using the calculator.

WHAT CAN YOU DO WITH A BROKEN CALCULATOR?

Once in a while you will find a calculator where some of the keys do not work. Don't throw that calculator away. It is a source of thought provoking problems. For example, if the 7 and 8 keys do not work, ask the students to tell how they would use the broken calculator to add 278 and 879 or multiply 75 times 38.

HOW ABOUT USING CALCULATORS TO CHECK ANSWERS?

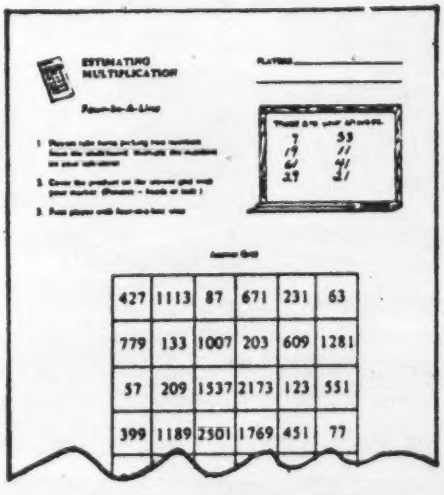
Checking answers on a calculator can be dangerous if it is done too frequently. Put yourself in the position of a student who has just spent 5 minutes of hard labor doing a long division exercise and then checks it painlessly in 5 seconds on a calculator. What is learned? The student learns that school is unreal and that the division exercises should have been done on the calculator in the first place. However, there are times when checking on a calculator makes good sense. You have just had the student complete 20 multiplication exercises at the 2 digit x 2 digit level. Try giving each student 4 coupons which they can trade in for a free calculator check. Three or four students are checkers and are equipped with calculators. The students can get one of their problems checked anytime they want to give up a coupon. Using a calculator provides feedback, and keeps the students interested.

COUPON
CALCULATOR CHECK
COUPON

COUPON
CALCULATOR CHECK
COUPON

HOW CAN YOU INCREASE THE STUDENTS' ESTIMATION SKILLS?

One favorite estimation game is "4 in a line". To play we put 8 numbers on the chalkboard. Students play in pairs. The first player chooses two numbers from the chalkboard and multiplies them on the calculator. If the answer is on the 6 x 6 answer grid, the student covers the product with a marker. Four markers in a line in any way determines a winner.



A check mode can also be used to encourage students to estimate.

In this example the student places a decimal point in the measures, finds the sum with the calculator, and is pretty sure the answer is correct if the calculator sum checks with the ✓ number on the sheet.

Name: _____

SIZING UP METRIC MEASURES

Place the decimal point in each number contained in the sets below so the measurement makes sense. Then compare your total with the ✓ number for the set.

Set I: Height of a man: 180 meters

Length of a football field: 914 meters

Length of an automobile: 550 meters

Height of a basketball hoop: 304 meters

Length of notebook paper: 280 meters

✓ number: 102.02

Another way to reinforce estimation skills is to play the game Target Multiplication. Two players take turns following the flow chart. In game 1 the first player enters 25, pushes [X] , enters another number of his choice and pushes [X] . If he is on target (680 to 710) he wins, if not he passes the calculator. The other player makes an estimate, pushes [X] and the play continues until one player "hits the target".

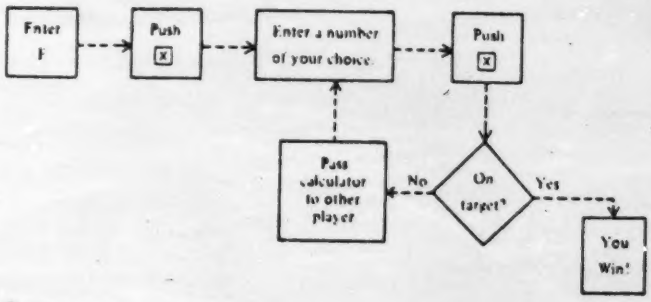
ESTIMATING MULTIPLICATION

PLAYER #1 _____

PLAYER #2 _____

Target: Multiplication

Using only the [X] and numbers, try to "hit the target."

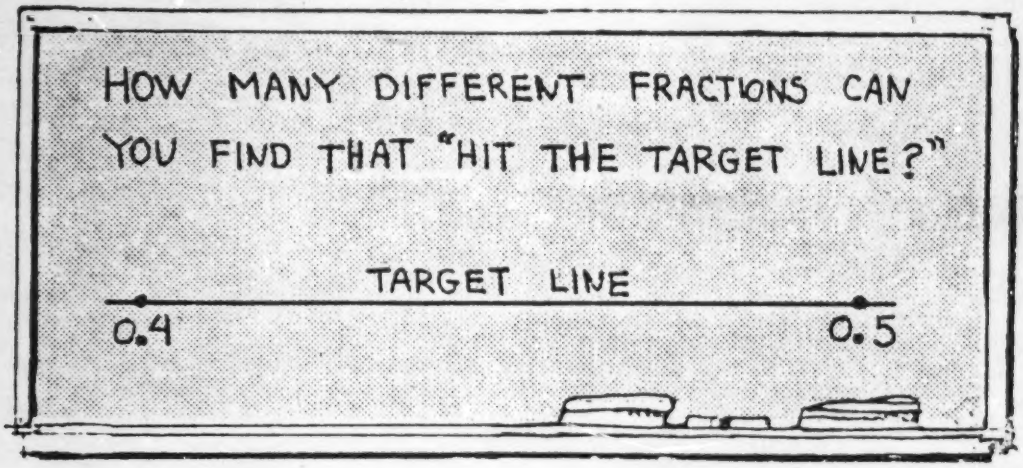


Try these games

GAME 1	GAME 2	GAME 3
F = 25	F = 12	F = 15
Target Area	Target Area	Target Area
680 710	370 400	490 510

HOW CAN THE CALCULATOR BE USED TO EXTEND TEXTBOOK LESSONS?

Many lessons in the textbook can be extended with calculator activities. For example, an extension of a paper and pencil lesson changing fractions to decimals is shown on the chalkboard.



Activities of this type can help students relate their knowledge of fractions to decimals. By using a calculator students can check out a large number of fractions in a short period of time.

ARE THERE WAYS TO USE THE CALCULATOR OUTSIDE THE CLASSROOM?

The availability of calculators in the home makes possible many outside the classroom activities. A favorite home project of our students is to find the most expensive food (cost per gram) in their kitchen cupboard. For example, is the unit price of a 42 gram can or nutmeg that cost $0.86 more expensive than a 454 gram can of coffee that cost $3.08?

Students will enjoy this type of home assignment because with a calculator successful division computation is within the reach of every student.

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